

DEPARTMENT OF THE INTERIOR

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MINING METHODS AND COSTS OF THE PARK CITY
CONSOLIDATED MINES CO., PARK CITY, UTAH



BY

GLOYD M. WILES

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MINES CO., PARK CITY, UTAH^{1/}

By Gloyd M. Wiles^{2/}

INTRODUCTION

The property of the Park City Consolidated Mines Co. is situated in the northeast part of the Park City mining district 1 mile east of the town of Park City. The elevation at the collar of No. 1 shaft is 7,250 feet.

Park City is a town of approximately 4,500 population lying about 30 miles east of Salt Lake City. The two are connected by an oiled State Highway, which is cleared of snow in winter and maintained in first-class condition by the State throughout the year.

The district is served by branches of the Denver & Rio Grande Western and Union Pacific Railroads, each operating on a daily schedule, except Sunday. These two railroads have constructed 1½ miles of joint track from the town to the Park City Consolidated Mines Co. loading tipples, located 200 feet from the portal of the adit that leads to No. 1 shaft.

During the first 10 months of 1935 the company produced 62,193 tons of ore averaging 0.0364 ounce of gold and 12.85 ounces of silver to the ton. The total metal content amounted to 2,224 ounces of gold and 803,828 ounces of silver and netted \$412,455.80 in smelter returns after freight and metallurgical-treatment charges were deducted. Total production of the property, from its inception in 1928 to November 1, 1935, has been 4,525 ounces of gold and 2,428,023 ounces of silver. These amounts were extracted from 155,135 tons of ore.

ACKNOWLEDGMENTS

The author acknowledges the assistance of W. P. Goss, assistant superintendent, W. R. Storms, resident geologist, and John Worcester, mine surveyor, of the Park City Consolidated Mines Co. for their part in the preparation of this paper.

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- 1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgement is used: "Reprinted from U.S. Bureau of Mines Information Circular 6880."
2/ General Superintendent of Park City Consolidated Mines Co., Park City, Utah, and one of the consulting engineers, U.S. Bureau of Mines.

HISTORY

Mineral was found in the Park City district in 1869; the first discovery of importance, however, was the location of the Ontario Mine in 1872 by Rector Steen. This mine, which now belongs to the Park Utah Consolidated Mines Co., has produced in excess of \$34,000,000 and paid approximately \$14,000,000 in dividends.

The Park City district has produced 9,000,000 tons of ore yielding \$8,000,000 in gold, 210,000,000 ounces of silver, 2,000,000,000 pounds of lead, 400,000,000 pounds of zinc, and 56,000,000 pounds of copper. The total value of the metals produced is estimated at \$292,500,000 and dividends to date at \$68,000,000.

The original holdings of the Park City Consolidated Mines Co. consisted of claims located in 1920; certain adjacent properties were then acquired and consolidated. The company was incorporated in 1928 and ore was discovered 256 feet below the surface in No. 1 shaft early in the following year.

GEOLOGY AND ORE DEPOSITS

A comprehensive and detailed report of the geology of the district has been compiled by J. M. Boutwell.^{3/} The sediments of the Carboniferous and Triassic ages, comprising the Park City anticline, are (1) 1,290 feet of calcareous sandstone, limestone, and shales (Thaynes formation); (2) 700 feet of shale (Woodside formation); (3) 600 feet of Park City limestone (Park City formation); and (4) 1,700 feet of Weber quartzite (Weber formation). These are underlain by a limestone bed known as the Wasatch Lime Formation. Figure 1 is a section through the property.

There are two distinct types of ore deposits in the district - (1) lode deposits in fissure veins and (2) bedded replacement deposits at certain definite horizons in the Park City and Thaynes formations overlying the Weber quartzite.

So far, the ore mined at the Park City Consolidated Mines Co. property has been confined to lode deposits in fissures in the Weber quartzite, but several horizons favorable to bedded replacement deposits lie within the property boundaries and are being prospected. On the whole, the fissure ores are high in silver, with small amounts of gold, lead, and zinc. The bedded replacement deposits of the district carry good silver values, are high in lead and zinc, and also usually carry small amounts of copper.

All of the major fissures that have been explored to date in the property have been productive. These are the Silver, Roosevelt, and East Crescent fissures. They are shown on the accompanying map (fig. 2). The McKinley

^{3/} Boutwell, J. M., Geology and Ore Deposits, Park City District, Utah: U.S. Geol. Survey, Prof. Paper 77, 1912, 231 pp.

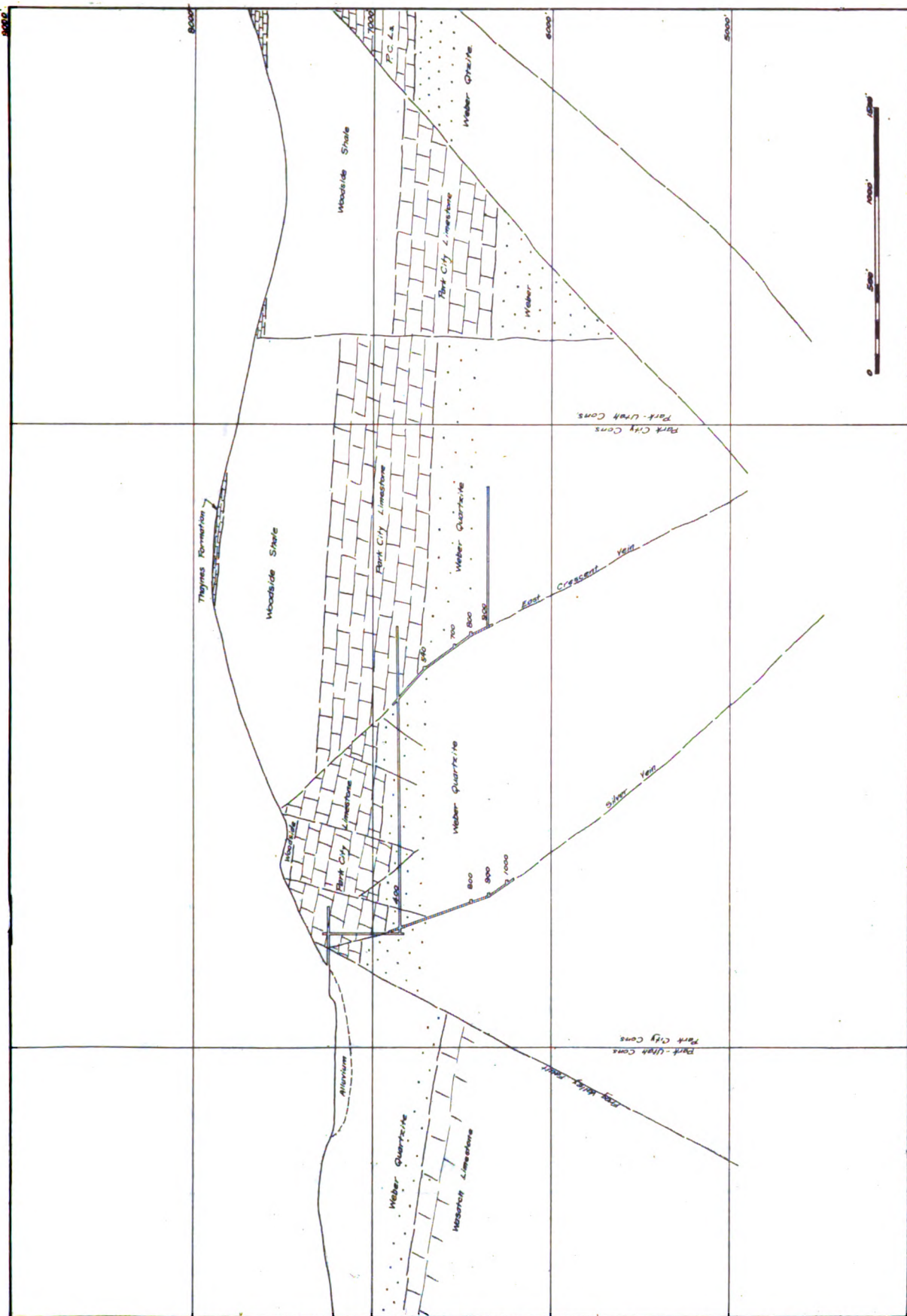


Figure 1.- Section through property of Park City Consolidated Mines Co.

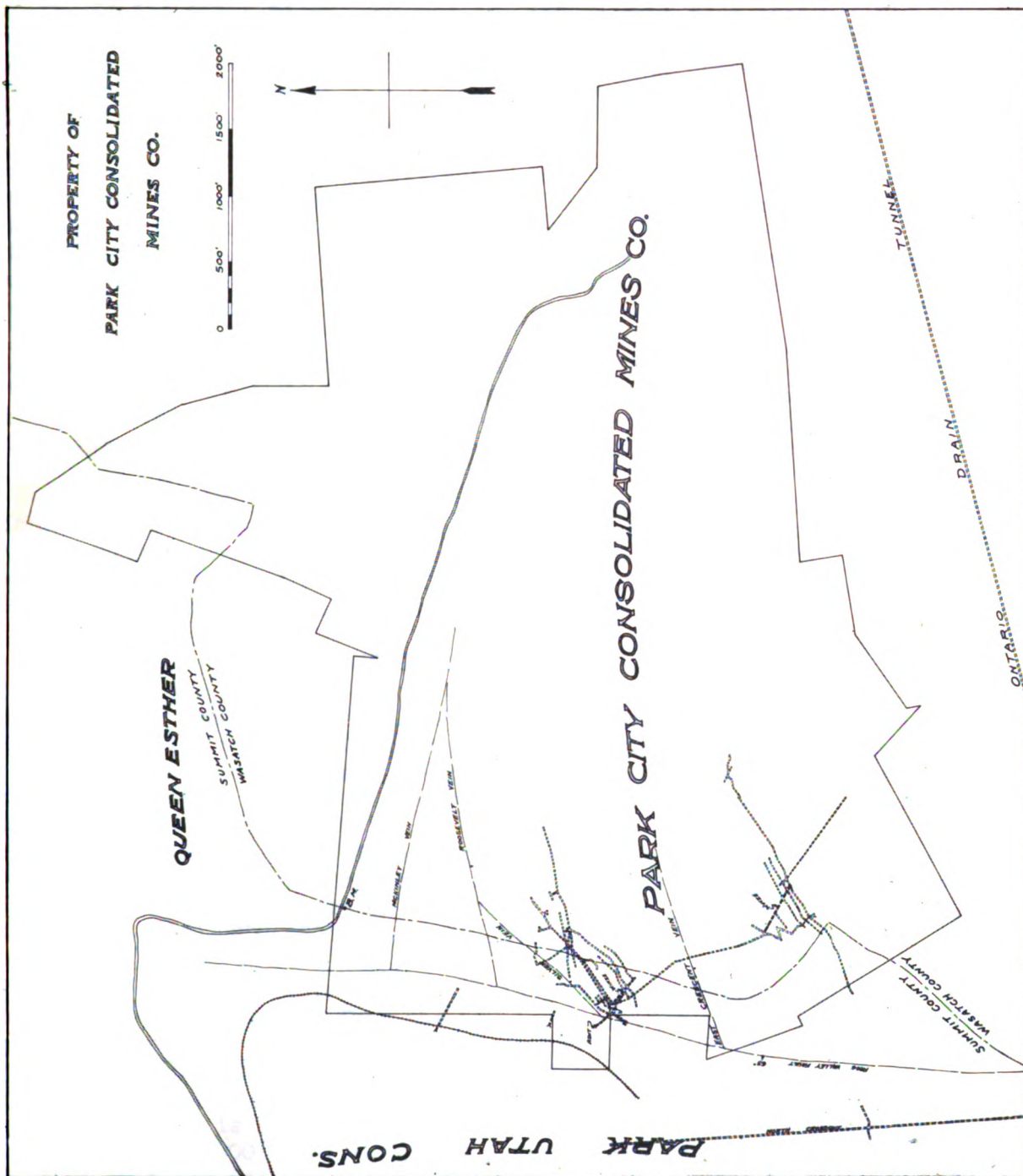


Figure 2.- Silver, Roosevelt, and East Crescent fissures.

Fissure, which, judged by surface indications, appears to be the one having the greatest displacement and which may be the greatest producer of the property, has not yet been explored underground. This fissure lies to the north of the other major fissures and has an east-west strike. The others strike northeast-southwest. The indications are that they will join the McKinley as development work progresses eastward. Based on previous experience in the district, it is thought that the spots where ore is most likely to be deposited are at the junctures of these fissures.

Two classes of ore are extracted from the fissures. The lower portions of the ore bodies are sulphide material carrying such ore minerals as sphalerite, galena, tetrahedrite, argentite, pyrite, and the ruby silvers, usually in a quartz gangue. Some calcite, chert, mangano-calcite (a manganese, magnesium, calcium carbonate), and small amounts of barite are also present as gangue minerals.

The carbonate or oxidized ores found in the oxidized areas above the sulphide zone are composed of the oxidation products of the sulphide minerals listed above; the silver is largely in the form of chlorides. For the most part the same quartz gangue is present as in the sulphide zone.

The grade of the ore mined at the property so far is considerably lower than that produced by other mines in the Park City District. It is thought that a better grade may be produced as the mine is deepened. An analysis of samples taken from each level in the sulphide zone shows that the grade is increasing with depth.

PROSPECTING AND EXPLORATION

A small amount of diamond drilling was done during the past year, but the shattered condition of the veins and surrounding quartzite country rock results in slow progress and low core recoveries. The information obtained was too meager to justify the cost involved.

Exploration is carried on by the usual crosscutting, drifting, and raising. A vertical shaft was sunk to the 400 level, and an incline winze was then sunk down the dip of the fissure to the 1,000 level. Drifting was done on the 700, 800, 900, and 1000 levels from this winze.

A crosscut that intersected the East Crescent Fissure 1,400 feet to the southeast was driven from the 400-level station of the main vertical shaft, and a winze was sunk here to the 900 level. Drifts have been driven on the 500, 700, 800, and 900 levels of this winze.

A crosscut is now being driven to connect the Silver and East Crescent fissures on the 900 level to afford a better ore-transfer system, to provide an exit for the water lying below the 900 level to the Park Utah drain tunnel, and to improve the ventilation of the mine. This crosscut should intersect and determine the value of several small fissures that were encountered in the 400-level crosscut, if they extend to this depth. This

level lies immediately above the top of the water table as maintained by the Ontario drain tunnel, which passes near the property boundary; it will provide ready access to all the fissures at all times, whether or not pumping of the lower levels is in process.

It is planned to intersect the McKinley fissure in two places on the 900 level during the next year. The fissure is traceable for approximately 1 mile and is confined entirely within the boundaries of the Park City Consolidated Mines Co. property. As stated previously, this fissure is believed to be the strongest of all those on the property, and high hopes are held for the extraction of a large tonnage of ore from within its walls.

DEVELOPMENT

As previously stated, the mine is served by one vertical shaft from the surface to the 400 level and two inclined winzes to their present bottoms on the 900 and 1,000 levels in the East Crescent and Silver Fissures, respectively. The vertical shaft is to be deepened in the near future to handle the Silver and Roosevelt fissure ores directly and to hoist from the 900 level any ore from the East Crescent and any other fissure that may be opened later. This level will be a main-haulage entry. This will permit the elimination of one hoist that is now in operation on the Silver fissure and thereby effect a saving in operating costs.

Ore is now hoisted in cages from the 400 level to the surface adit and trammed directly to the railroad cars. When the vertical shaft is deepened, the caging will be discontinued, and the ore will be hoisted by means of a skip and drawn from pockets in the adit.

The single-compartment winze on the East Crescent fissure will be increased in size as it is sunk below the 900 level. Three compartments, 5 feet by 5-1/2 feet in the clear, are to be utilized in the extension. A double-drum electric hoist will then be installed on the 900 level to operate two skips in balance.

METHODS OF SAMPLING

Daily samples are cut of new faces in the stopes and development headings; grab samples also are taken from the cars trammed.

The commercial value of the carbonate or oxidized ores cannot be determined by visual examination in many places, and the cut samples, therefore, are an important guide to daily mining operations. All assays of cut samples are plotted on stope maps made on tracing cloth; these are brought up to date each day by the mine sampler after the assays have been made. The samples are taken in the morning and assayed in the afternoon. The maps are held in looseleaf pocket notebooks, which are carried by the shift bosses on their beats and used as a guide in pointing stope and drift rounds from day to day.

All ore mined is shipped directly to the United States Smelting, Refining & Mining Co. concentrating plant at Midvale, Utah. The shipments are sampled by the smelting company, and controls are run by the smelting company, and by the mining company. After comparisons are made, if splitting limits are not met, umpire assays are made by reputable umpire assayers in Salt Lake City.

PHYSICAL CHARACTERISTICS OF ORE AND ENCLOSING ROCKS

The fissures, or veins, have dips varying from 50 to 75° from the horizontal, but mainly stand at about 60°. The ore matrix varies widely in its physical properties, particularly with respect to its hardness. The veins may be composed of hard massive quartz, friable sugar quartz, or an uncemented conglomeratelike material. Certain sections of the latter material have been pick-mined successfully. The vein thickness ranges from 2 to 30 feet, and many pockets of ore are found in both the hanging and foot where the walls are not clearly defined. Both walls are generally quartzite, although occasional thin beds of limestone are found. They vary greatly in strength and range from massive blocky quartzite to a shattered gravel-like material. The limestone beds are usually fairly firm but occasionally are found to be soft and sticky. Swelling then takes place within a few hours after they are opened to the atmosphere.

In addition, in certain portions of the Silver and Roosevelt fissures a porphyry dike has been encountered that forms one or both walls of the ore. This porphyry, like the softer limestones, swells and sloughs badly when opened to the atmosphere.

It will be appreciated readily that walls and ore matrices such as these demand individual attention in the various parts of the mine and present individual problems of wall support if safe, clean mining is to be accomplished.

STOPING

Shrinkage stopes were used in the mine prior to February 1935. Investigation at this time indicated that from 25 to over 100 percent dilution was occurring in the shrinkage stopes that were in operation. In addition to this, two shrinkage stopes caved before all the broken ore could be drawn out, and several hundred tons of broken ore were lost. The new management appointed at that time immediately decided upon a change in the mining method and took steps to effect the changes as soon as possible. A decision was made to use incline cut-and-fill stoping wherever feasible. It was found, however, that open-stope mining with timber support could be utilized to advantage in some cases where the veins were narrow and the walls were not too weak. Moreover, in the previous development for shrinkage stoping, the upper levels of the mine had not been driven far enough to provide access to the tops of all of the stopes being mined. This necessitated the use of some form of open stoping at least until access was provided for bringing in filling through development of the levels above. It is of interest to note that many tons of new ore were developed by this work on the upper levels.

The varying condition of the walls encountered in the open stopes necessitated individual plans of timber support for this type of mining. In some places, stulls with headboards on the hanging walls were found to be sufficient. In other sections it was necessary to lag off the hanging wall completely, and in some cases even the footwall had to be lagged off, although the dip of the vein was more than 55° from the horizontal.

The drifts are timbered with 8- by 8-inch Douglas fir through all ore shoots and other sections where the ground requires support. When timbering through ore (fig. 3) sills are placed under the track in hitches cut in solid foot and hanging walls. Blocks are placed on the caps over the posts, and a bridge cap or stringer is placed over the blocks from foot to hanging. These bridge caps are then lagged over with a double thickness of 2- by 12-inch by 5-foot Douglas fir.

Chutes are spaced on 15-foot centers and stope sills are started over the drift. The raise through the ore and the silling over the lower drift furnish information as to the width of the vein and the character of the walls, so that the method of mining can be selected. If an open-stulled stope is started (fig. 4) and later work discloses that this method is unsuitable, the footwall is swept clean, and fill is run in from above. Then the stope is continued as a cut-and-fill stope, provided, of course, that the upper level development has been extended to the top of the stope.

Stopes are carried through from level to level, no ore pillars being left. After a stull stope is completed and swept clean it is filled with waste. The cut-and-fill stopes, of course, are filled as stoping progresses.

The incline cut-and-fill stopes are developed by driving three-compartment raises with a chute installed on each side of a timbered manway on 100-foot centers between levels (fig. 5). At the end extremities of the stopes, raises are started from the level and inclined to the right or left to delimit the ore.

When an incline cut-and-fill stope is started, the first cut is taken from the raise in such a manner that the back will incline upward toward the raise at about 50° from the sill on each side. After the ore is cleaned out, waste is run into the stope until it is within about 2 feet of the back and parallel to it. Two-inch lagging is laid on the waste for a floor, and the next slice or cut is taken. The height of the slice ranges from 6 to 12 feet, depending on the strength of the walls involved. When the cut has progressed as far upward as the walls will permit for safe, clean mining, the floors are swept clean and taken up, and another run of waste is added. The same lagging is then replaced on top of the fill, within 2 or 3 feet of the new back, as a floor for the second cut.

The history of the district with respect to the amount of development required per ton of ore mined indicates that approximately the right amount of waste will be taken from development headings to fill the openings made through ore extraction.

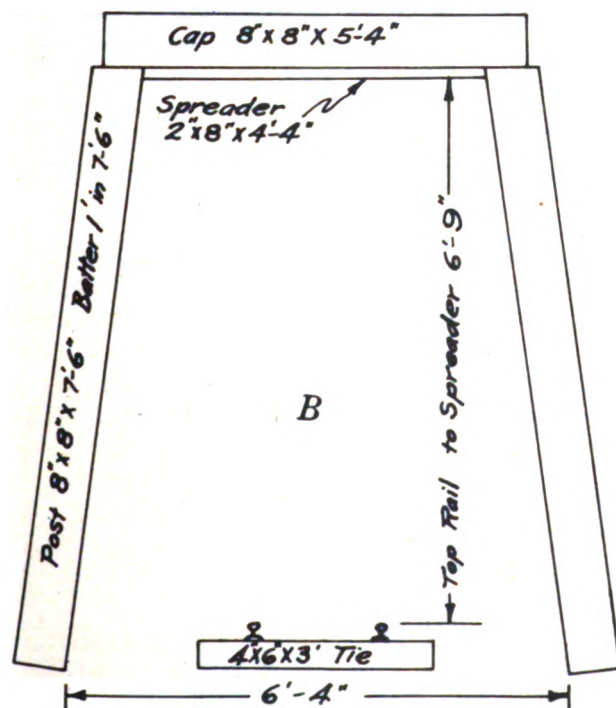
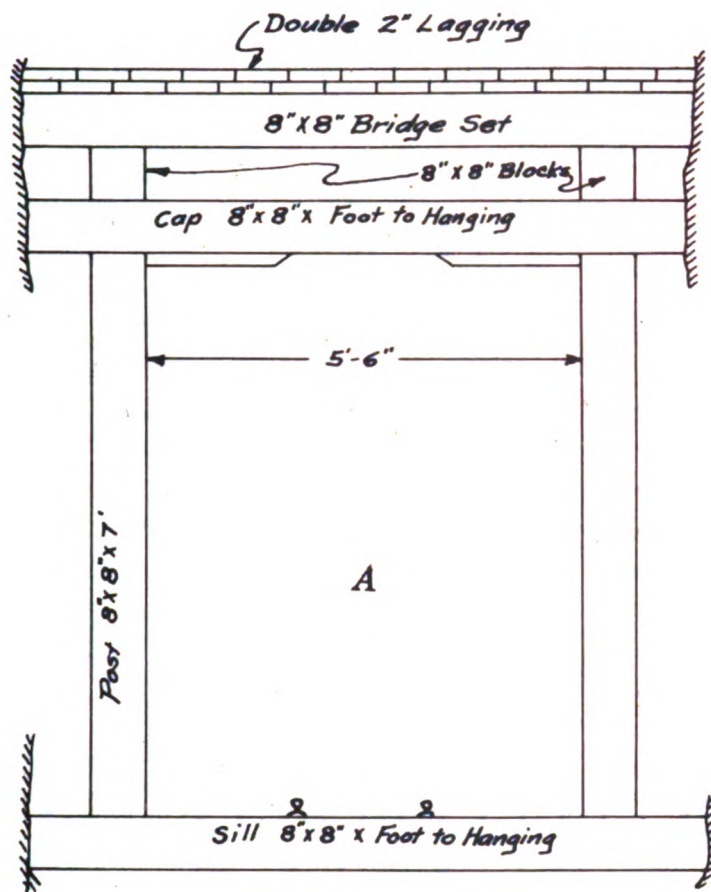


Figure 3.- Standard drift set: A, In ore; B, in waste.

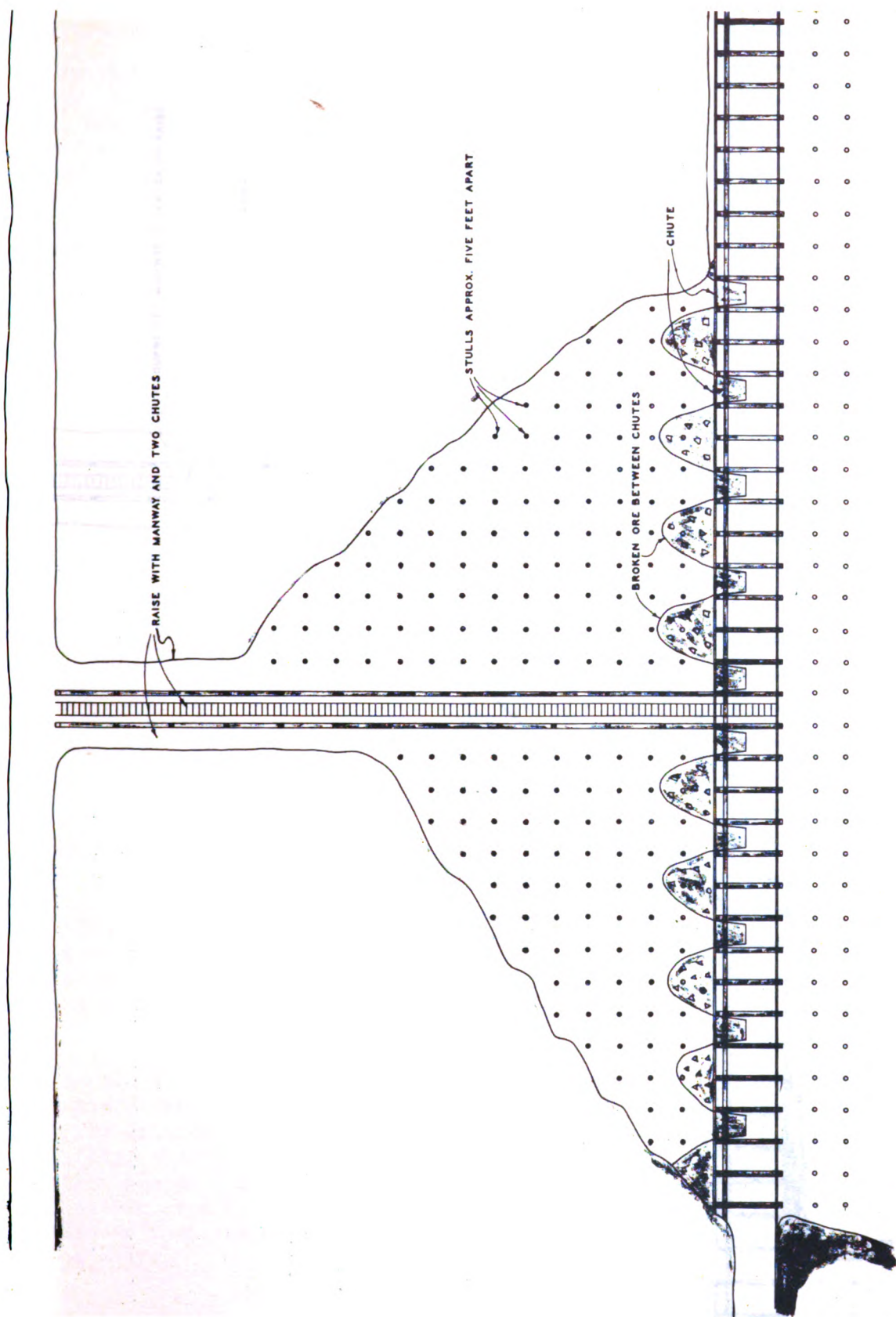


Figure 4.- Open-stalled slope.

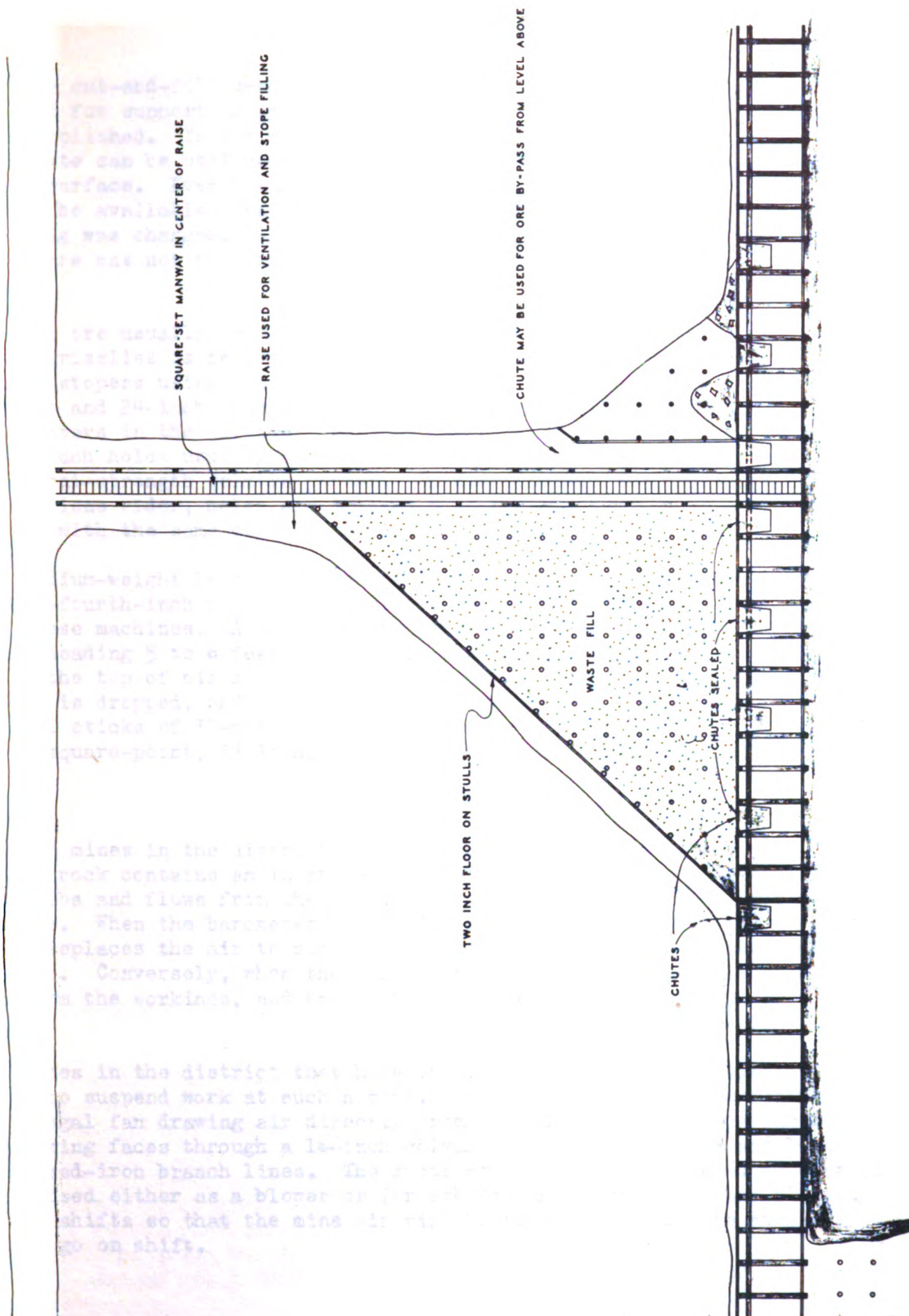


Figure 5.- Inclined cut-and-fill stope.

The cut-and-fill method has reduced very materially the cost of timber required for supporting the blocky, shattered walls where clean mining is to be accomplished. In the orderly operations of a cut-and-fill stope, development waste can be utilized for fill as it is made instead of being hoisted to the surface. Even though shrinkage stopes will absorb this waste, they may not be available when needed, which was the case at the time the method of mining was changed. Another advantage gained by the change was that the broken ore was not tied up so long in the stopes before shipment could be made.

The ore usually breaks very fine, and no secondary blasting or hammering on the grizzlies is required. Most of the stoping is done with light, hand-rotated stopers using 1-inch quarter octagon steel and having the regulation crossbit and 24-inch changes. Short holes are spaced approximately on 18-inch centers in the narrower sections where the walls are difficult to maintain. Such holes usually are loaded with one and one-half to two sticks of 30-percent-strength gelatin powder. In places where the walls are firmer and the sections wider, holes are drilled 5 to 8 feet deep and loaded somewhat heavier with the same strength powder.

Medium-weight Leyner drills are used in drifting and crosscutting. One and one-fourth-inch round lugged steel, having the usual crossbit, is used with these machines. A miner and two muckers on each shift advance a 6- by 8-foot heading 5 to 6 feet per shift. The miner sets up a crossbar and drills the top of his round, while the muckers clean out the drift. Then the bar is dropped, and the bottom holes are drilled. Usually 12 holes and 60 to 80 sticks of 30-percent-strength powder suffice to break the round. No. 4, square-point, 33-inch, D-handle shovels are used for mucking.

VENTILATION

All mines in the district have a peculiar ventilation problem. The country rock contains an inert gas, probably nitrogen and carbon dioxide, which ebbs and flows from the workings in accordance with the barometric pressure. When the barometer is falling this gas enters the mine workings and so replaces the air to such an extent that even a carbide lamp will not burn. Conversely, when the barometer is rising, the air flows into the rock from the workings, and the most remote heading will contain pure fresh air.

Mines in the district that have inadequate artificial ventilation are forced to suspend work at such a time. The company has a 30-horsepower centrifugal fan drawing air directly from the surface and delivering it to the working faces through a 16-inch galvanized-iron trunk line and 10-inch galvanized-iron branch lines. The ducts at the fan are arranged so that it can be used either as a blower or for exhausting. Four hours are allowed between shifts so that the mine air will be as pure as possible when the workmen go on shift.

HAULAGE

Stope chutes are designed with 24- by 30-inch openings and usually have 2-inch stop boards for gates. From pockets and main ore passes, however, the chutes usually are provided with arc gates made from 3/8-inch iron.

All underground tracks are 18-inch gage and laid with 20-pound rail on 4- by 6- by 36-inch ties spaced on 24-inch centers. Twenty-cubic-foot roller-bearing side- and end-dump cars are used throughout. The surface track from the collar of the shaft to the ore-loading dock is laid with 30-pound rail, with the same gage and tie spacing as elsewhere. All tramming is done by hand except that between the collar of the East Crescent fissure winze and the 400-level station of the vertical shaft, where an electric storage-battery locomotive pulling a 10-car train is used. The tramming from the collar of the vertical shaft to the tippie is accomplished by two men per shift; two cars are hoisted at a time.

The vertical shaft has two compartments and a double-deck cage that is counterbalanced by a weight equal to the cage plus half the live load. At present, an 80-horsepower, electric, double-drum hoist operates the cage and counterweight in this shaft. The rope speed is 450 feet per minute. A new hoist is being installed at the surface, which has a 15,000-pound dead-load capacity per drum and a rope speed of 1,000 feet per minute. The tonnage capacity of this shaft will be increased several times by the new hoist. The winzes are single compartment and equipped with single-drum electric hoists. Both winzes are inclined, and ore is hoisted by means of skips.

MINE EQUIPMENT

The surface plant includes a timber framing shed with a power saw, a storage warehouse, and a substation recently installed. The substation contains one bank of transformers of 1000 Kv-a capacity for 44,000- to 440-volt service, and another bank of 600 Kv-a capacity for 44,000- to 2,300-volt service. In addition, the plant contains an assay laboratory, an electric shop, machine shop, a steel-sharpening and blacksmith shop, and two air compressors. The air compressors are electrically driven, one having a capacity of 500 cubic feet of free air per minute and driven by a 75-horsepower motor, and the other of 550-cubic-feet capacity and driven by a 100-horsepower motor.

There is also a small change room and a dwelling for the superintendent, which includes offices located in the basement.

Four centrifugal pumps capable of lifting 1,100 gallons of water per minute from the 900 level to the surface have been installed. These pumps are connected in series and are driven by a 75-horsepower motor. Two centrifugal motorpumps have been installed on a truck and are used for sinkers in the Silver fissure winze, which is now being deepened to the 1,100 level. These pumps deliver the water to a sump on the 900 level, where it is settled and then lifted through the station pumps, previously described, to the surface. This station-pump setup, of course, will be discontinued early in the coming year when the connection is completed to the Park Utah drain tunnel.

The organization of the mine is as follows:

President and consulting engineer
 General superintendent
 Assistant superintendent
 Geologist
 Sampler
 Surveyor
 Helper
 Assayer
 Helper
 Supply clerk
 Cost and time clerk
 Stenographer
 Electrical and mechanical engineer
 2 Electricians
 2 Helpers
 Steel sharpener
 Blacksmith
 3 Mechanics
 3 Pumpmen
 2 Timber framers
 2 Shift bosses
 2 Jigger bosses
 160 Men

The Park City Consolidated Mines Co. has been paying the prevailing wage scale of the Park City district. During the period covered by this report wages were as follows:

Underground

Per 8-hour day

Shift bosses	\$6.75
Jigger bosses	5.75
Shaft timbermen	5.75
Shaft miners	5.75
Shaft timbermen helpers	5.25
Timbermen	5.25
Timbermen helpers	4.75
Miners	5.25
Muckers	4.75
Trammers	4.75
Motormen	5.25
Cagers	5.00
Skiptenders	5.00
Motor helpers	4.75
Hoistmen	5.50
Mucking-machine operators	5.25
Top trammers	5.00
Pipemen	5.25

SurfacePer 8-hour day

Master mechanic	\$6.50
Blacksmith	6.00
Mechanic	5.25
Compressor man	5.25
Pumpman	4.75
Laborer	4.75
Electrician	5.25
Truck driver	5.25
Sampler	4.75
Survey helper	4.75

During this period no contract or bonus system was in effect, although at present the development headings are being worked under a contract system that is effecting appreciable reductions in costs. The contractor is given a fixed price per foot of advance and is required to furnish his own explosives. The company sells him explosives at cost.

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TABLE 1. -- Underground costs -- dollars per ton ore hoisted

	Labor	Supervision	Compressed air, drills, steel, etc.	Power	Explosives	Timber	Other supplies	Total
Development (ore & rock)	\$0.687	\$0.045	\$0.084	---	\$0.079	\$0.103	\$0.012	\$1.010
Mining	.889	.044	.053	---	.075	.150	.014	1.225
Transportation	.645	.032	---	\$0.049	---	---	.021	.747
General	.037	.001	---	.010	---	---	.007	.055
Surface	.141	.009	---	.020	---	---	.005	.175
Pumping	.049	.002	---	.140	---	---	.010	.201
total	2.448	.133	.137	.219	.154	.253	.069	3.413

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TABLE 2. - Summary of cost in units of labor, power, and supplies

A. Labor (Man-hours per ton)	Development	Mining	Total
Breaking	0.546	0.479	1.025
Timbering	.051	.479	.530
Shoveling	.476	.479	.955
Hoisting and haulage	---	---	.515
Supervision	---	---	.130
General	---	---	.053
Total labor underground	1.073	1.437	3.208
Labor percent of total cost	68.0	74.2	71.7
Average tons per man shift			2.49
B. Power and supplies			
Explosives (pounds per ton)	.397	.552	.949
Timber (board feet per ton)	4.40	5.86	10.26
Power (kw.-hr. per ton)			19.60
(1) Air compression			3.53
(2) Transportation			3.59
(3) Pumping			10.27
(4) Ventilation			.74
(5) Lighting and auxiliary power requirements			1.47
Power and supplies (percent of total cost)			20.4
C. Percent of total cost	29.7	35.9	

TABLE 3. - Details of development costs - typical headings

Headings	Advance, feet	Direct costs			Cost, feet
		Labor	Supplies	Total	
Drifts					
702 D	103	\$589.60	\$274.05	\$863.65	\$8.38
805 D	101	537.39	262.18	799.57	7.92
902 D	40	228.75	121.79	350.54	8.76
902 AD	66	363.25	142.12	505.37	7.66
Crosscuts					
908 D	52	161.75	49.86	211.61	4.06
Raises					
542 R	108	544.56	153.31	697.87	6.46
703 AR	52	361.75	54.73	416.48	8.01
815 R	39	163.87	30.73	194.60	4.99
819 R	64	644.75	198.08	842.83	13.17
928 R	34	150.25	56.13	206.38	6.07
929 R	9	46.38	3.86	50.24	5.58
934 R	54	234.00	92.14	326.14	6.04
Totals	722	4,026.30	1,438.98	5,465.28	7.57

Explosive consumption was as follows:

(Hercules Gelamite 30%)		Pounds per foot advance	
Drifting		6.39	
Raising		3.6	
Crosscuts		6.0	

Timber consumption was as follows:

		Board feet per foot advance	
Drifting		4.96	
Raising		2.80	
Crosscuts		.00	